SAVONIA

THESIS - **BACHELOR'S DEGREE PROGRAMME**
TECHNOLOGY,COMMUNICATION AND TRANSPORT

PERFORMANCE TESTS FOR PORTABLE SOUNDPROOF MODULAR SPACE SYSTEM

- TEST PARAMETERS: CO_2 CONCENTRATION, AIR VELOCITY, NOISE LEVEL, TEMPERATURE, HUMIDITY.

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SAVONIA UNIVERSITY OF APPLIED SCIENCESTHESIS ABSTRACT

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Abstract

The aim of this thesis was to conduct performance tests on a small office called BOX. The specific location of the box was in the hall of Savonia University of Applied Sciences.

The experimenters took measurements during the spring break of 2020 and within a few weeks after the end of the spring break, and drew relevant graphs for more direct observation and comparison. The measured contents mainly included indoor carbon dioxide concentration, humidity, indoor and outdoor temperature and noise level. All the instruments used were provided by the school.

Through discussion and analysis of the experimental results, the experimenters obtained the advantages and disadvantages of the box. Secondly, the author analyzed the applicable population and reasons for this small office, as well as the development direction of the box in Finland and China.

The relevant conclusions drawn were: This kind of box can be promoted in China, and many people think that this kind of box will bring convenience to people. An increase in the number of people in the box will cause an increase in carbon dioxide concentration. The noise level outside the box will be affected by the voices of teachers and students in the school hall, but the inside of the box will not be affected.

However, there are some suggestions for improvement. By placing green plants in the box, the increase in carbon dioxide concentration can be suppressed. By adding blinds in the box direct sunlight can be prevented and the privacy of the box can be increased. Also, by adding some decoration or equipment in the box, it will attract more people.

Keywords

Indoor air quality, small office, modular space, combination of main parameters, CO2 concentration, temperature, noise level.

CONTENTS

1. INTRODUCTION

This thesis mainly introduces a small office room, which we call a box. Nowadays, there are more and more similar boxes. The main reason is that this box can be placed no matter what the occasion, and it can provide a safe and secret place for people. This brings great convenience to people. And carried out environmental monitoring of its internal and external environment, including indoor carbon dioxide concentration, air velocity, brightness, temperature, humidity and indoor and outdoor noise levels. Through the analysis of the experimental results, combined with the actual conditions of China and Finland, we discussed the advantages and disadvantages of the box, the applicable population and the improvement plan, and finally reached a conclusion.

2. THE SCOPE OF THE THESIS

The scope of the paper mainly includes environmental monitoring of a small meeting room national indoor air quality guidelines in Finland and China. Some experimental tests and results, discuss part concerning the suitable population of small meeting rooms, potential places. And some advantages and disadvantages.

At the end, we gave some improvement programs.

3. INDOOR AIR IN CHINA AND FINLAND

3.1 Requirements for indoor air classifications in Finland

The following table (Table1) mainly shows some of the requirements for indoor air classifications in Finland.

Table 1. Requirements for indoor air classification in Finland(Mervi Ahola,Jorma Sateri,Laura Sariola,2018)

	S1	S2
Carbon dioxide concentration (ppm)	<350	<550
Radon concentration ($Bq/m^{3)}$	<100	<100
$PM_{2.5}$ ($\mu g/m^{3)}$	<10	<10
$PM_{2.5}$ indoor/outdoor	<0.5	<0.7
Stability of environment (%of operating time) office and school spaces residential spaces.	90% 90%	90% 80%

S1: The technical target values for thermal environment in the indoor air categories.

S2: It shall be used to specify the target level for indoor environment during the design phase of the construction project.

The outdoor air in Finland is the cleanest in the world, and this can also be clearly felt during our time studying in Finland. But at the same time, fine particles are the biggest cause of the environmental burden of diseases in Finland . Therefore, the target values of the PM2.5 concentration and the in-out ratio are strictly set. In order to achieve the goal, the efficient filtration must be designed.(Mervi Ahola,Jorma Sateri,Laura Sariola. Revised Finnish classification of indoor climate 2018)

3.2 Requirements for indoor air classifications in China

The following table mainly shows some of the requirements for indoor air classifications in China.

Table 2. Requirements for indoor air classification in Finland (China Standard Press,2003)

Parameter category	Unit	Standard value
Carbon dioxide concentration CO_2	%	0.10
Formaldehyde HCHO	mg/m^3	0.10
Respirable particles PM_{10}	mg/m^3	0.15
Total volatile organic compounds TVOC	mg/m^3	0.60
Radon Rn	Bq/m^3	400

In recent years, China has continuously increased environmental protection and ecological civilization construction. Atmospheric air pollution, smog and other conditions have been effectively decreased. With people's yearn for a better life, people began to pay more attention to indoor air quality. There are many kinds of indoor air pollution sources and it is not easy to detect. Nowadays people spend more than 80% of their time indoors on average. Therefore, indoor air pollution has greater harm and impact on human health.

The first major impact of indoor air pollution is "respiratory diseases such as sore throat, cough, pharyngitis", followed by "dry skin, itching, allergies and other symptoms." The other effects are: "early symptoms such as dizziness, dry eyes, drowsiness, and memory loss", "triggering childhood leukemia", "causing infertility in women or malformations of pregnant women and fetuses", "causing serious diseases such as adult lung cancer". The survey shows that people believe that the most harmful substance is formaldehyde, followed by benzene (toluene, xylene), and the other harmful substances are TVOC (indoor organic gaseous substance), PM2.5 (small particles), and ammonia. (Survey on the status quo of indoor air quality in Chinese households,2019)

3.3 Chinese Box

China has such a similar box, (see figure1 below) and it can now be seen in many places. But he is not like the box in the text, its main function is to provide a place for people to sing and watch movies. Therefore, it is also completely soundproof and will not affect others when used.

Figure 1. Chinese Box. (Time music,2020)

3.4 Chinese point of view

Such a small box is rarely seen in China. In many cafes there will be relatively large boxes that can accommodate 6-8 people. And it is completely soundproof, mainly used to talk about more private topics. So, I asked the coffee shop owner, the school teacher and two classmates, their comments are:

Coffee shop owner (32 years old): This box looks very good. If he puts 1-2 in the store, it may be better to provide a place for guests to talk privately.

School teacher (31 years old): The teacher doesn't really have many thoughts on the box. It has no great influence on students and teachers.

Student A (21 years old): He thinks that such a box can be placed in the school. If it is during lunch break or when it is noisy, it can provide a place for some students to study quietly.

Student B (21 years old): He thinks such a box can provide a lot of convenience but feels that adding a blind is better. This will make the box more private.

3.5 My own view

I think the ventilation system of the box is very good, and I will not smell any smell emissions from materials after running ventilation on for a long time. The design of the box is also very good. Because in this era, basically two or three people usually chat together and play together. Such a box can provide convenience for many people and does not take up much space.

4.NEEDS AND WISHES FOR SMALL MEETING ROOMS I.E. “BOXES”

I think this small meeting room is very convenient and suitable for many people on many occasions. First, there are many freelancers who do not want to work away from home. They need to find a special public place, a quiet place that will not be disturbed by others and have office conditions. Therefore, if the boxes are placed in cafes, drink shops, bookstores and other places, many people will find a comfortable office place easily.

Secondly, many corporate meeting rooms need to be reserved in advance, and meeting rooms are limited. If some staff temporarily need a place to conduct a short negotiation or conversation, if there is such a box, it will help the staff solve many problems.

Third point, the school library is not suitable for conversation, and the school does not provide other private places for teachers and students. Therefore, if a box is placed in the school, it can provide a quiet and private environment for teachers and students, and it will not disturb other people's learning.

Fourth point, everyone may encounter an event that needs to be handled urgently while in a public place. Putting one or two boxes in certain public places with conditions will also provide some help for people.

Due to the large population of China, I think this box can only be placed on special occasions, such as cafes, offices, and schools. Because in an overly densely populated place, if one or two are placed, people will look strange when staying inside. If they are placed too much, they will occupy too much space. More importantly, there is no need to make an appointment to use the box, and there is no time limit, so it is not very suitable for places with a large population. In Finland, even if the box is placed in a public place, it will not cause crowding, queuing or even scramble.

Experimental part

5.BOX SPECIFICATIONS

The experimental tests were carried out in one type of small meeting room, called BOX in this thesis. BOX looks like one example in Figure 2.

Figure 2. One example of a small meeting room.

The BOX specifications under study were:

Size: 3,5 m^2

Power: 220 V

Ventilation: 40-50 l/s

Weight: 640 kg

Size: Depth 1600 mm x Width 2400 mm x Height 2200 mm

BOX was located in the main entry hall of Opistotie campus in Savonia University of Applied Studies.

6.MEASUREMENT PLAN

The goal of the experimental tests is to measure various data inside and outside the box so that we can better understand the advantages and disadvantages of this kind of element in the point of view of the applicable population. We plan to complete tests in three to four weeks. Measurement tasks include indoor and outdoor noise level, indoor and outdoor air temperature, moisture, carbon dioxide concentration, brightness, and air velocity from conditioning system. And we shall measure a set of benchmark data when the school was unmanned (holiday week) for comparison with the data under normal school conditions.

7.MEASUREMENT PROCEDURE

7.1 Measuring instruments

Measuring instruments are given in Table 1 and you find some photos of them in Figures 3-8.

Table 3. Measuring instruments

Measuring component	Measuring device	component (unit)	valid range for meter
Carbon Dioxide	VALLOX	CO_2 (ppm)	
Light Meter	TES1336	LUX	
Humidity/Temperature	VWR TH300	R.H（%） T（℃）	0 % to 90 %: 0 °C to 35 °C (+32°F to +95°F) 0 % to 70 %: 0°C to 50°C (+32 °F to +122°F) Operating Temperature: 0°C to +50°C (+32°F to +122°F) Storage Temperature: −40°C to +60°C (−40°F to +140°F)
Temperature	FLUKE 50D	T（℃）	50S or 50D
Noise level	TES 1352A	N (dB (A))	30dB – 130dB
Air velocity	AVM-07	M/S	0-45m/s

Figure 3 Instrument for detecting air velocity.

Figure 4 Instrument for detecting noise level (A).

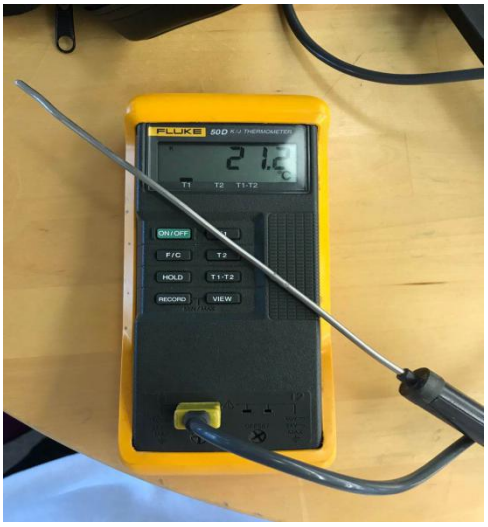

Figure 5 Instrument used to detect air temperature.

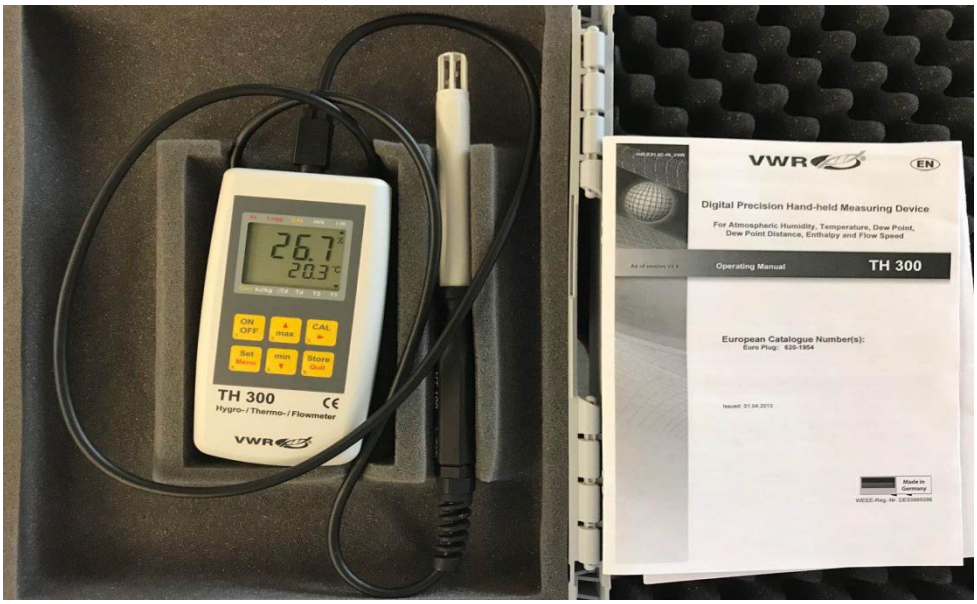

Figure 6 Instrument for detecting air temperature and moisture.

Figure 7 Instrument used to detect illumination.

Figure 8 Instrument for detecting carbon dioxide concentration

These are all the instruments we use in our experiments. All the instruments were portable and easily movable.

7.2 Measurement procedure

Temperature measurement

We place temperature measuring devices inside and outside the box to detect air temperature changes. We record data every five minutes. We take twenty minutes of continuous measurement for each speed range.

Moisture and carbon dioxide measurement

We only measure the changes of humidity and carbon dioxide concentration inside the box, and we will measure it separately according to different fan speeds and different numbers of people in the box. Each measurement is performed for twenty minutes.

Noise level measurement

We measured the noise conditions inside and outside the box and the top of the box at different wind speeds.

Air velocity measurement

We have measured wind speeds for different fan set(1,2,3) and in different position heights.(The high, middle, and low in the table represent the position of the head when the person is standing, the position of the head when the person is sitting, and the position of the table surface.)

Light meter measurement

I performed illumination detection in different locations, mainly around the lamp, on the table, and around the eyes of the person when sitting.

Here are some pictures of the box, on which I marked where we measured (Figure 9-12)

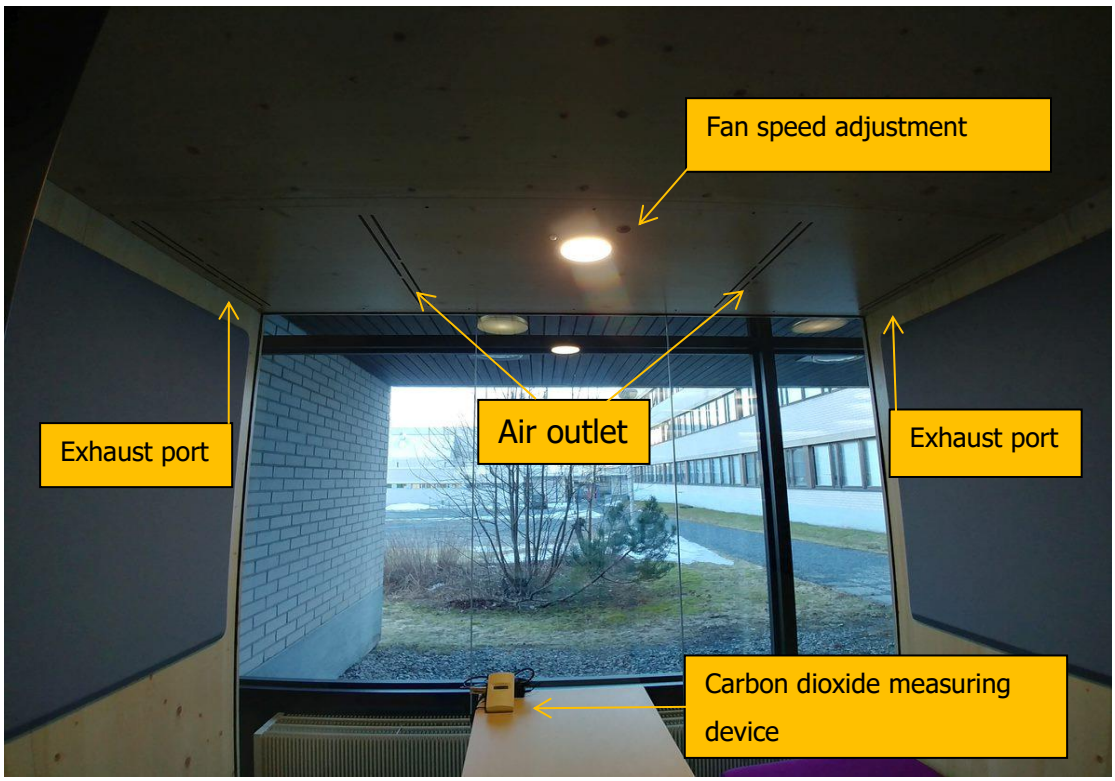

Figure 9 We put temperature and moisture measuring devices on the table for measurement.

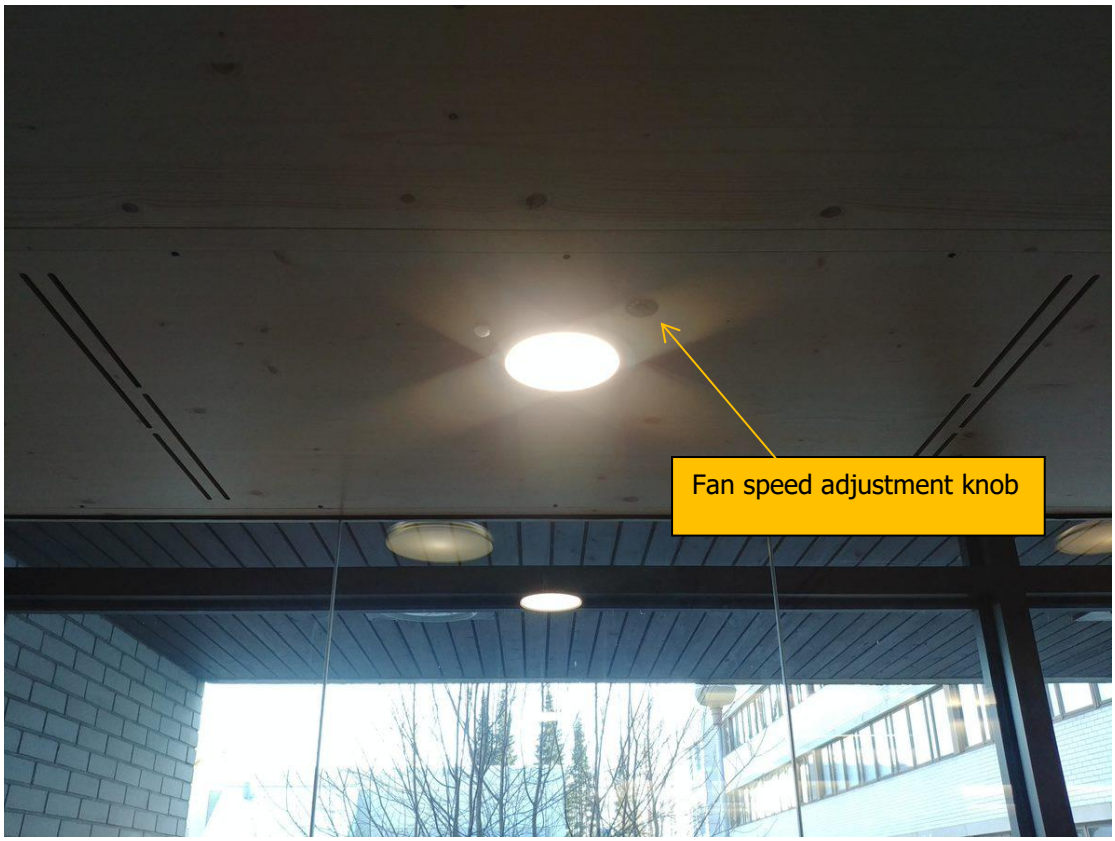

Figure 10 The knob is marked with 1, 2, 3, fan speed.

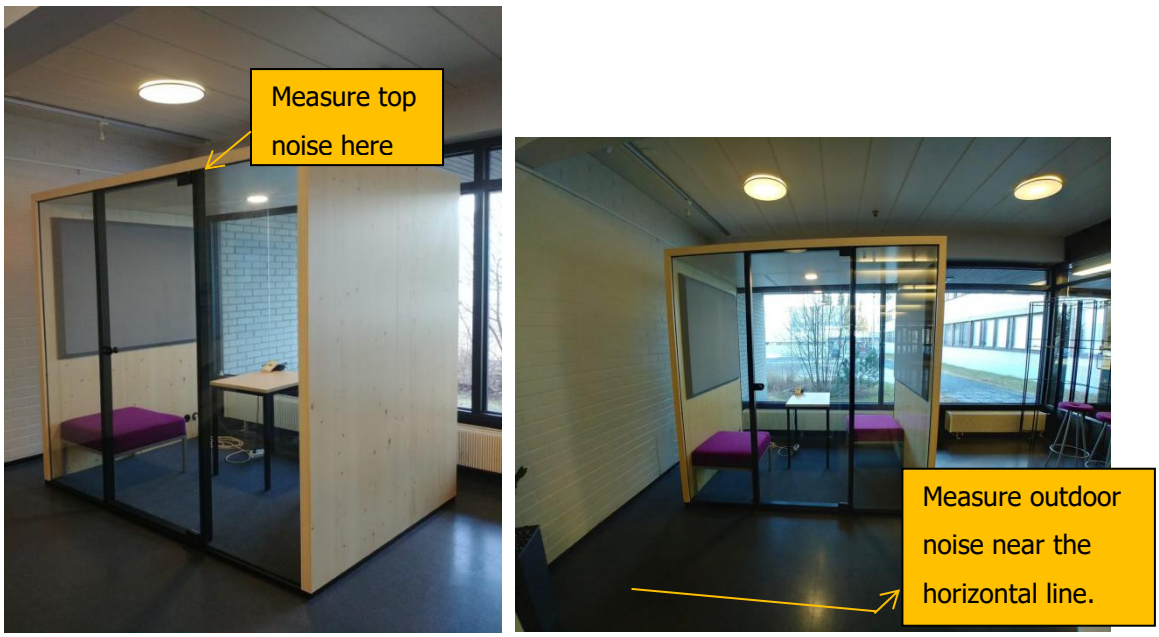

Figure 11 We measure noise indoors and at two places on the map.

Figure 12 I measure wind speed and illumination at three heights in the picture.

7.3 Experimental results

You can see the summary of the experimental tests carried out in March 2020 in Table X. The results are shown in Chart X There is more information of the measurements in Appendix 5-12

Table 4. Summary of the experimental tests

Date	Fan set	number of people in the box	test time with each fan set	number of the people in the hall
6.3.2020	1,2,3	0	20 min	a few(*
11.3.2020	**1,2,3**	**0**	**20 min**	**some**
6.3.2020	**1,2,3**	**1**	**20 min**	**a few(***
12.3.2020	**1,2,3**	**1**	**20 min**	**a few**
5.3.2020	**1,2,3**	**2**	**20 min**	**a few(***
9.3.2020	**1,2,3**	**2**	**20 min**	**many**

*): the benchmark tests during spring holiday week

7.3.1 Test results on holiday week

The results of tests carried out on spring break are shown in Chart 1. During the spring break, there was basically no one in the school. At this time, we measured a set of benchmark data to facilitate comparison with future standard data.

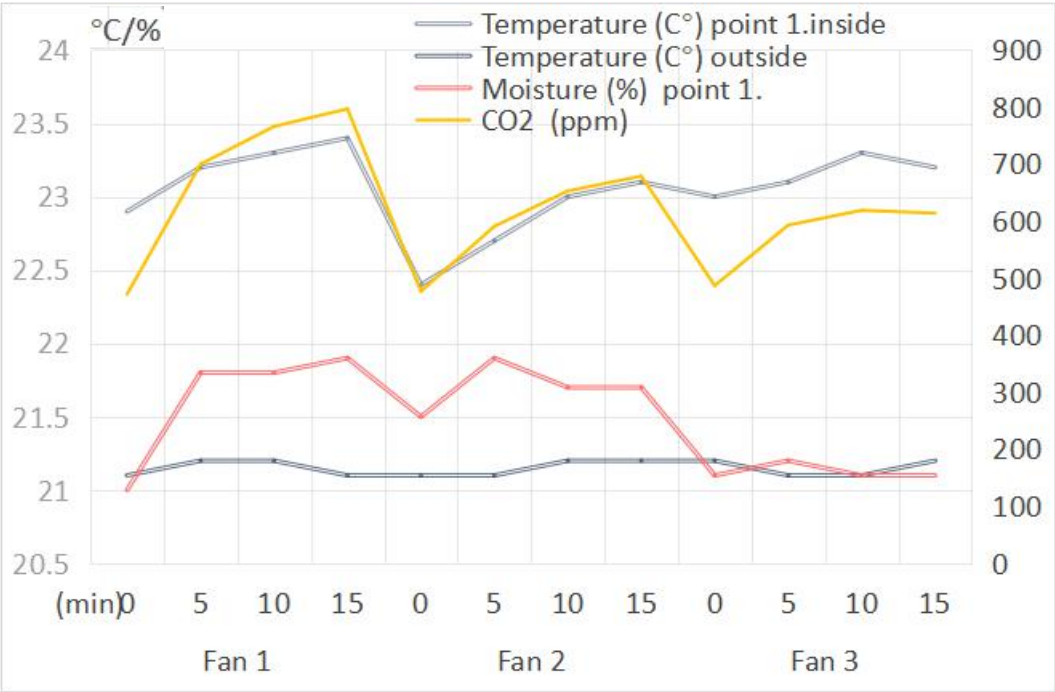

Figure 13. The results in the case 2 peoples in the box (home study week)

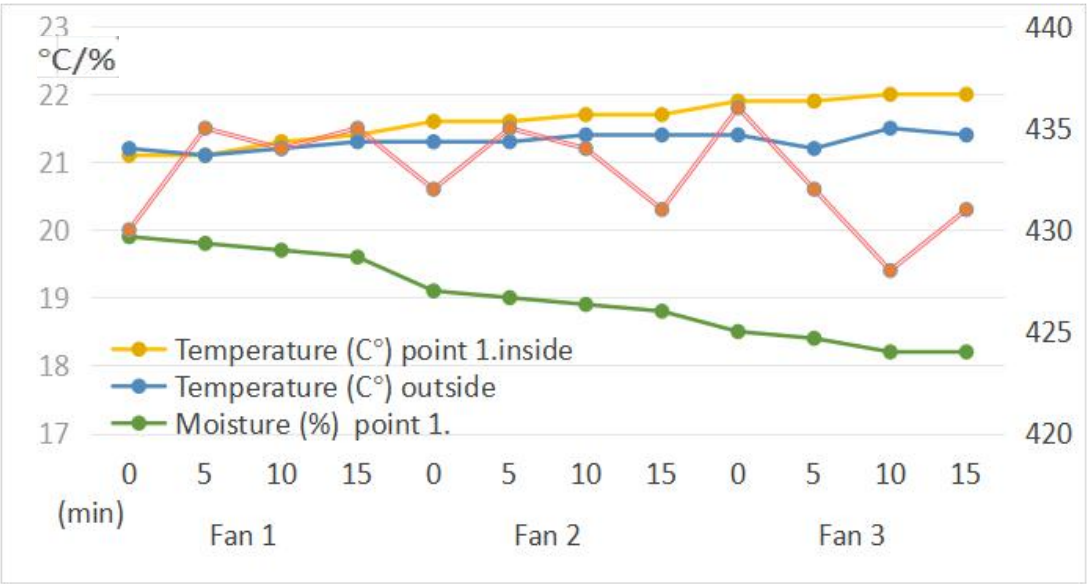

Figure 14. The results in the case 1 people in the box (home study week)

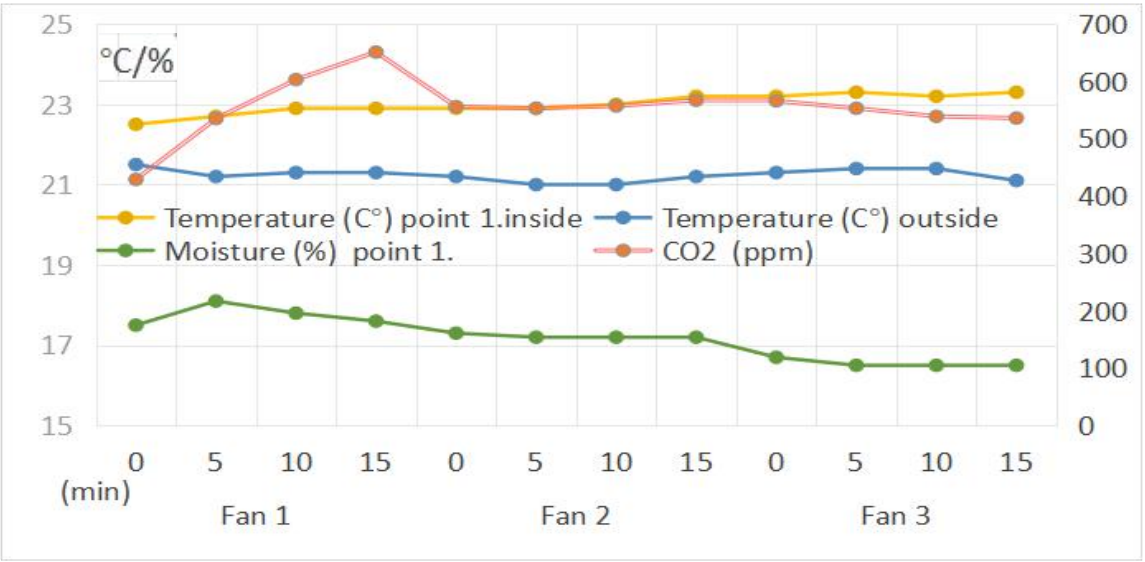

Figure 15. The results in the case 0 people in the box (home study week)

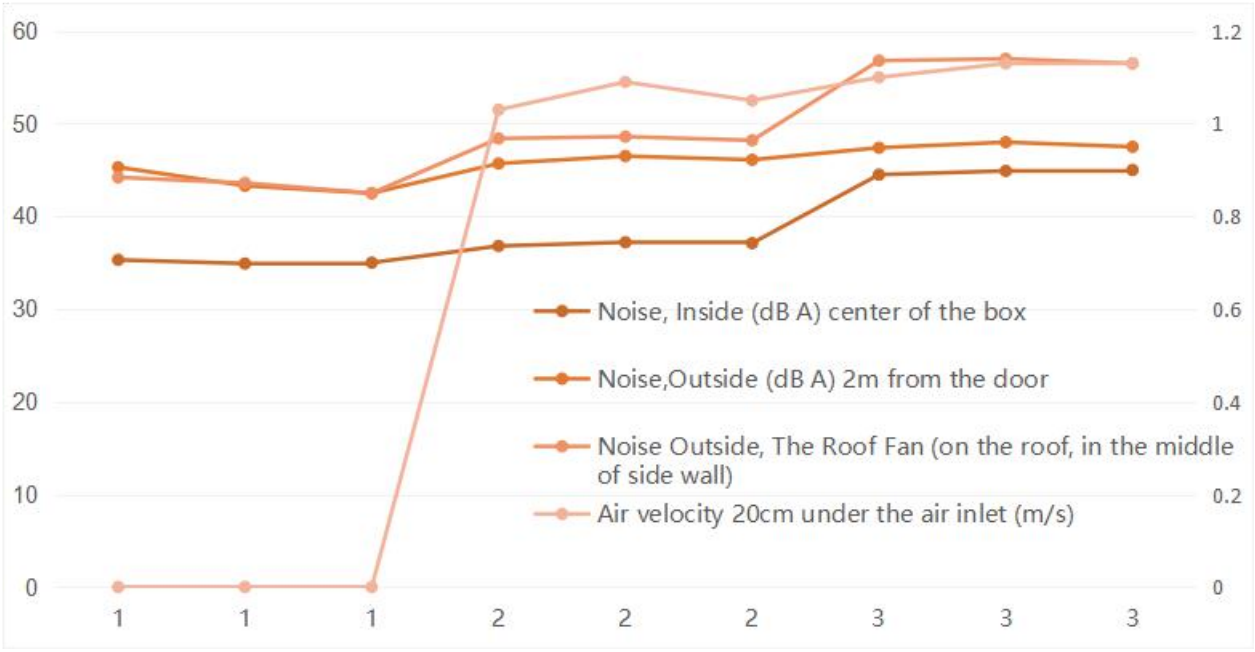

Figure 16. The results of the indoor and outdoor noise level and air velocity(home study week)

7.3.2 Test results on typical school week

The results of the experimental tests under normal circumstances, during typical school week are shown in Charts x.

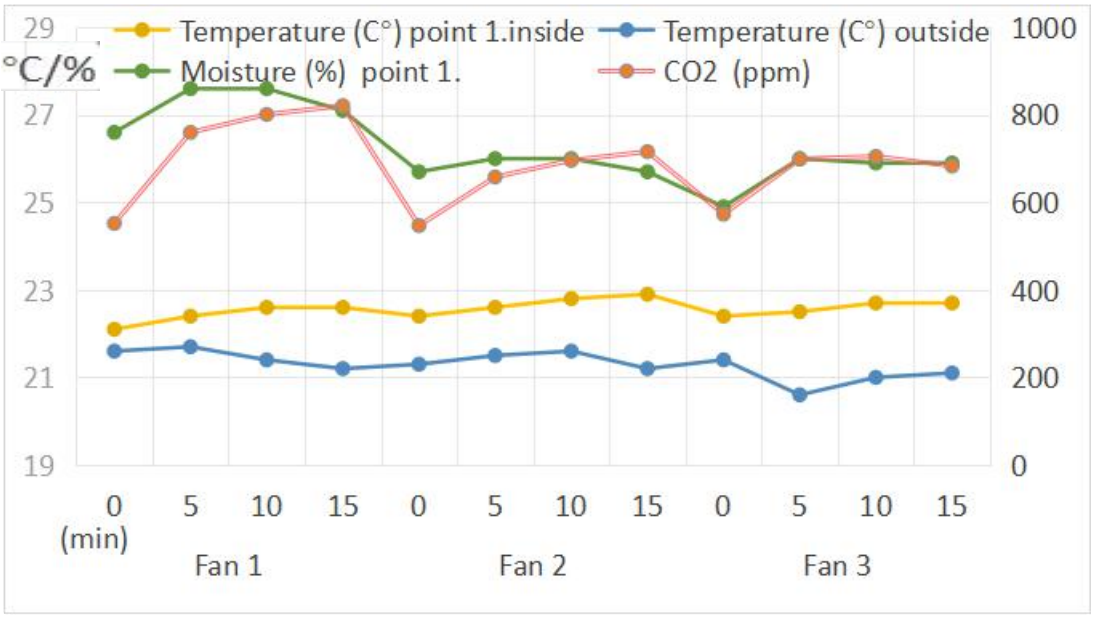

Figure 17. The results in the case 1 people in the box (school week)

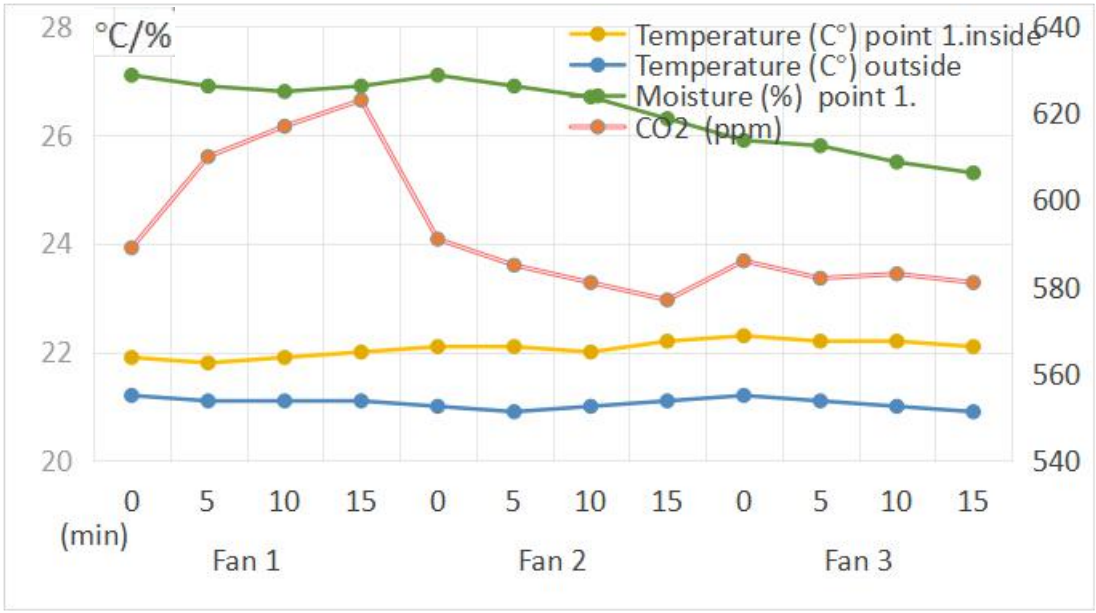

Figure 18. The results in the case 2 people in the box (school week)

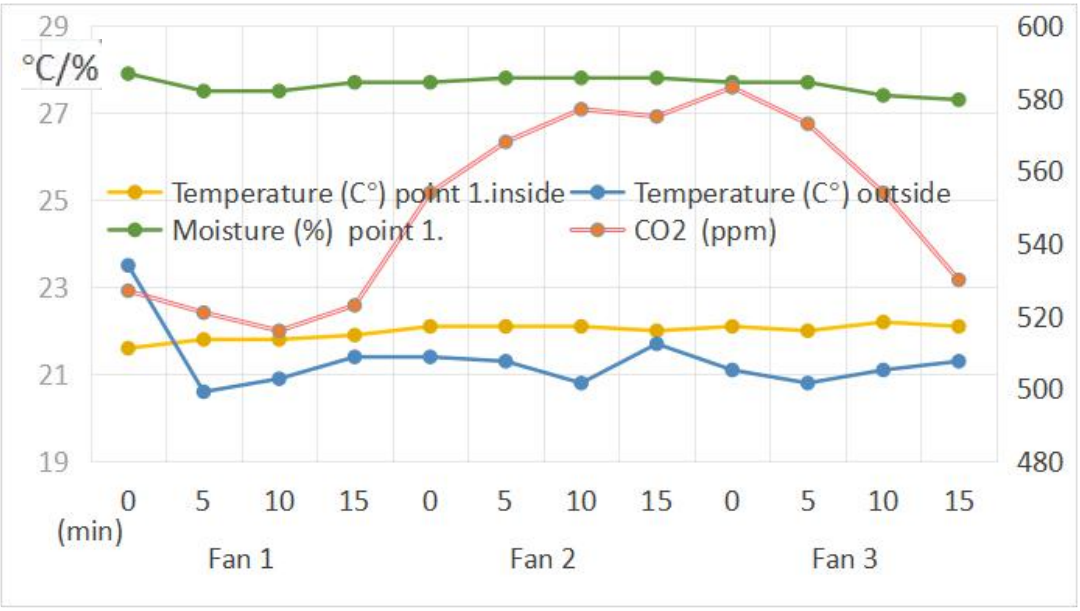

Figure 19. The results in the case 0 people in the box (school week)

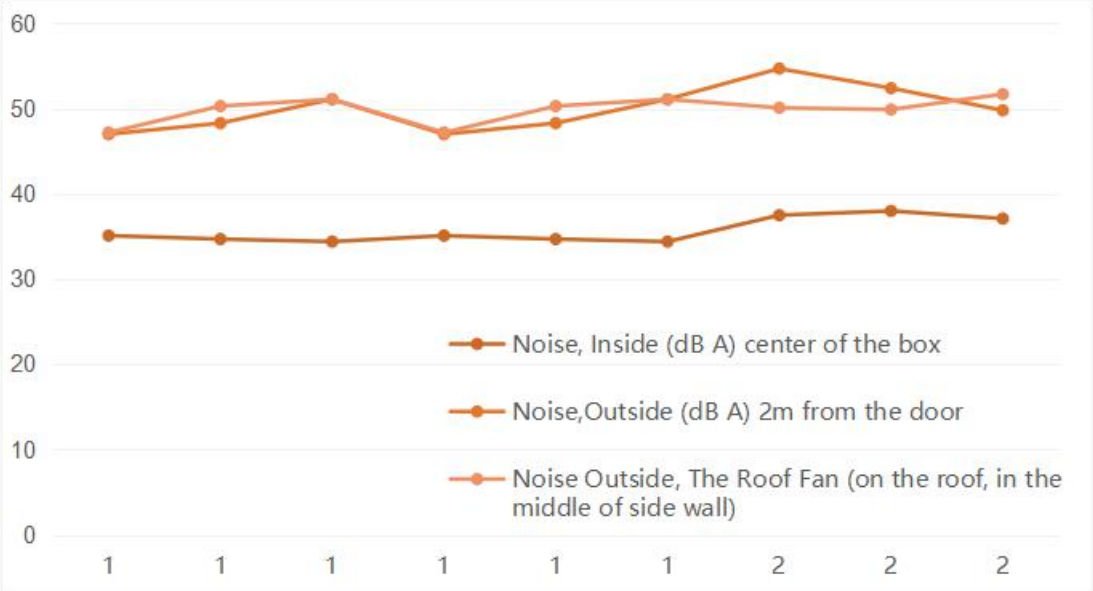

Figure 20. The results in the indoor and outdoor noise level (school week)

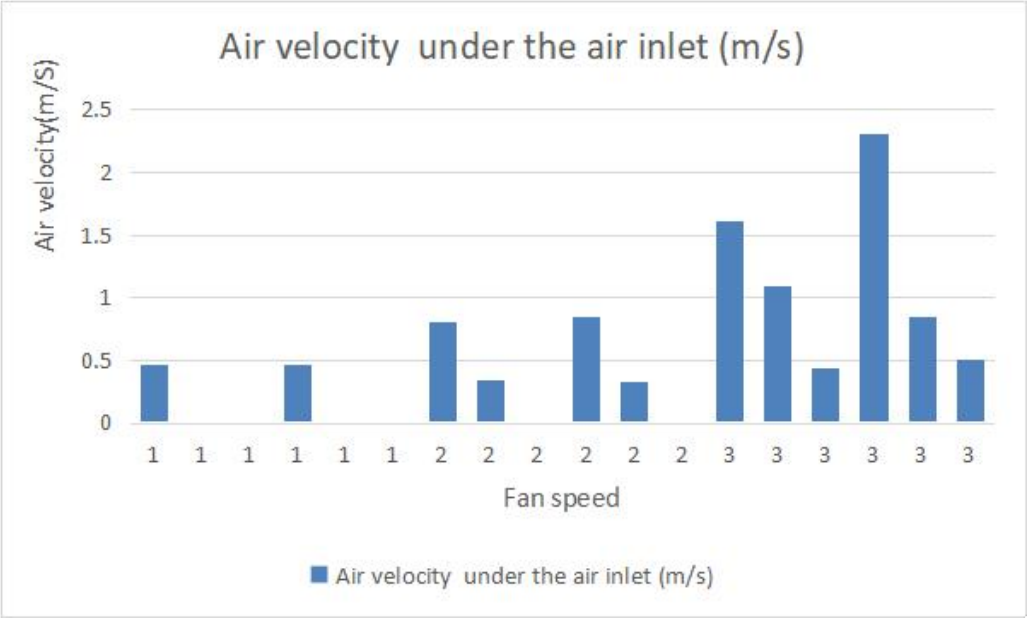

Figure 21. The results in the indoor and outdoor air velocity (school week)

8. DISCUSSIONS OF THE RESULTS AND CONCLUSIONS

8.1 Indoor noise level

According to the experiments, the noise level between indoor air in the box and outdoor air in the hall is actually not much different. But when people sit inside, they can hardly hear any sound outside. Most of the sound comes from inside the box, so the sound insulation of the box is very good. As for the voices in the hallway, most of them come from people talking, and the sound caused by the fan at the top of the box is not very loud, and if it is not close, it is basically not heard. As for the sound of the air conditioner, it will change according to different air velocities. When the fan speed is in the first gear, the sound is basically not heard. The second gear sounds as a slight wind, and the third gear will hear a relatively loud sound.

Next charts figure out the change of noise level in different situation (chart 1-2)

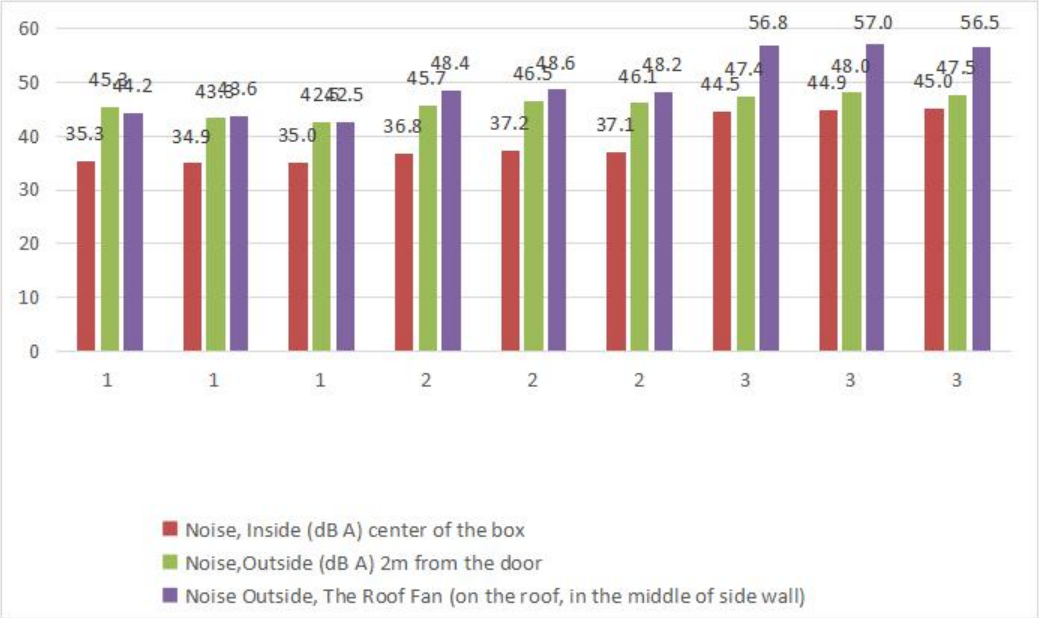

Figure22. Changes in noise level. (Home study week)

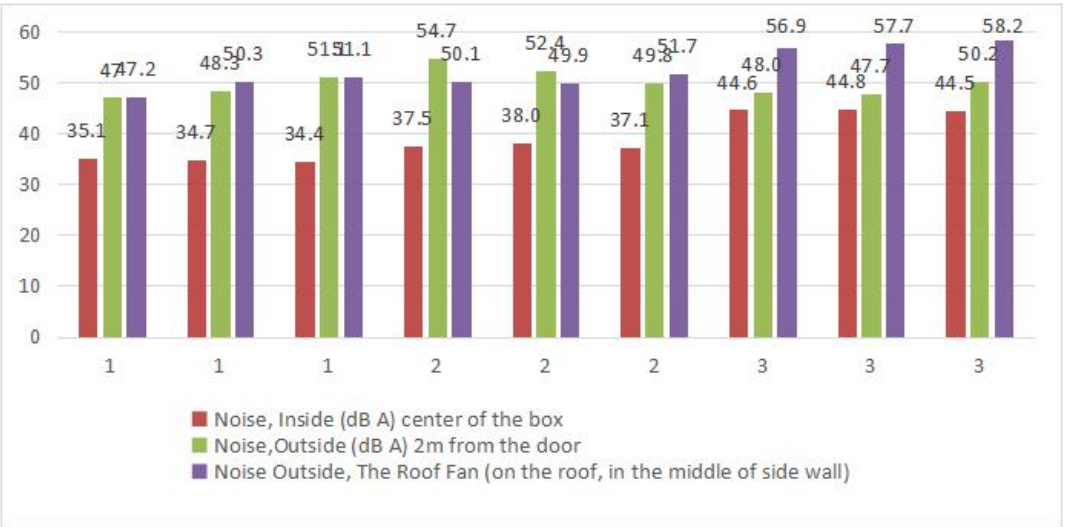

Figure23.Changes in noise level (school week)

According to the tables the noise level in the school hall during the normal school week has raised but it has not changed much compared to the noise level during home study week. The actions in the hall only affects the outdoor noise level, and basically has no effect on the indoor noise level. Therefore, the sound insulation inside the box is very good, and it can be protected from the outside.

8.2 Carbon dioxide concentration

Next charts figure out the change of carbon dioxide concentration in different situation (chart 1-6)

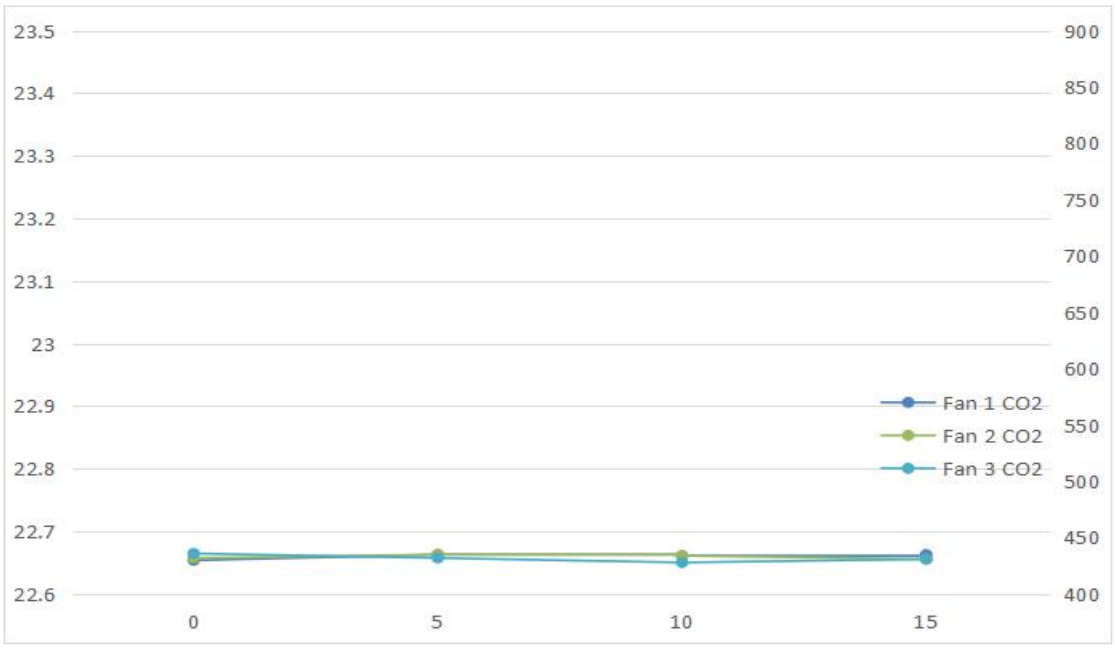

Figure 24. Changes in carbon dioxide concentration when 0 people are in the box. (Home study week)

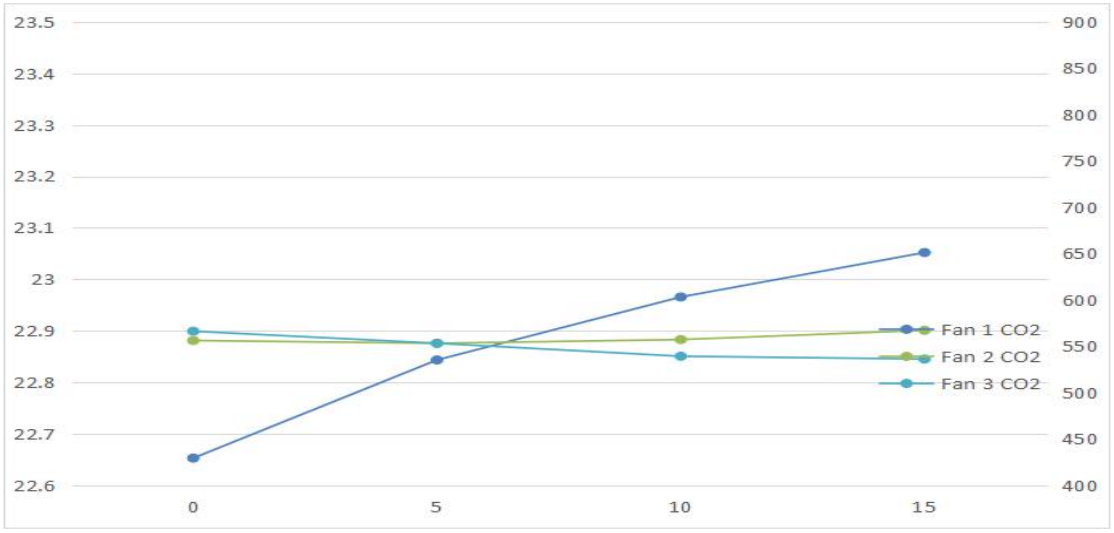

Figure 25. Changes in carbon dioxide concentration when 1 people are in the box. (Home study week)

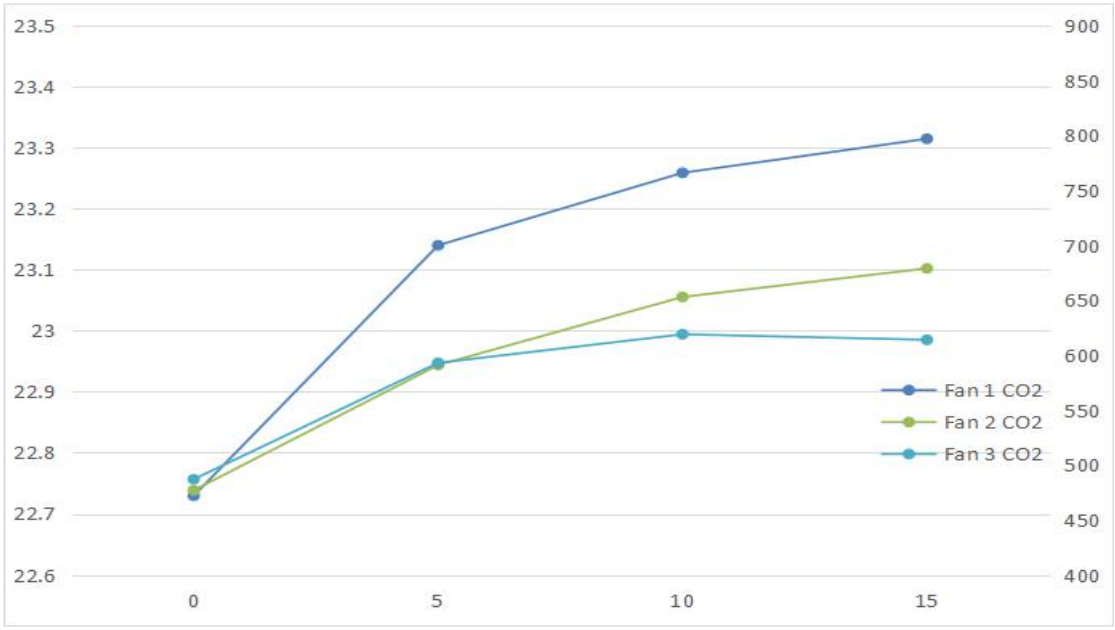

Figure 26. Changes in carbon dioxide concentration when 2 people are in the box. (Home study week)

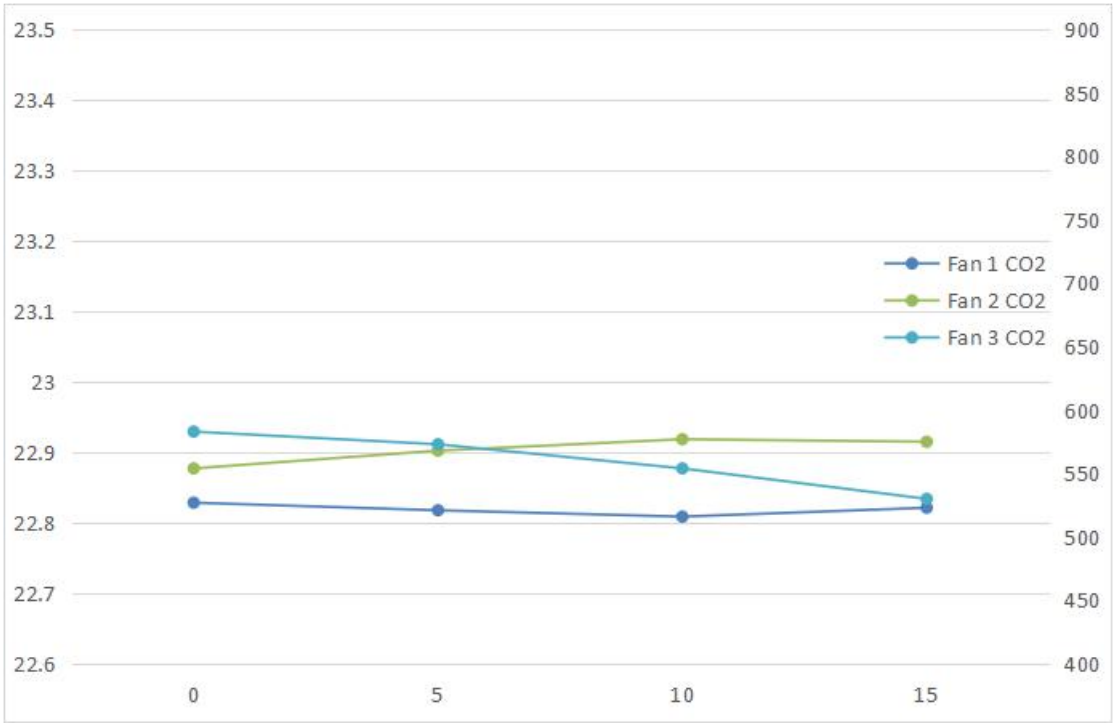

Figure 27. Changes in carbon dioxide concentration when 0 people are in the box. (school week)

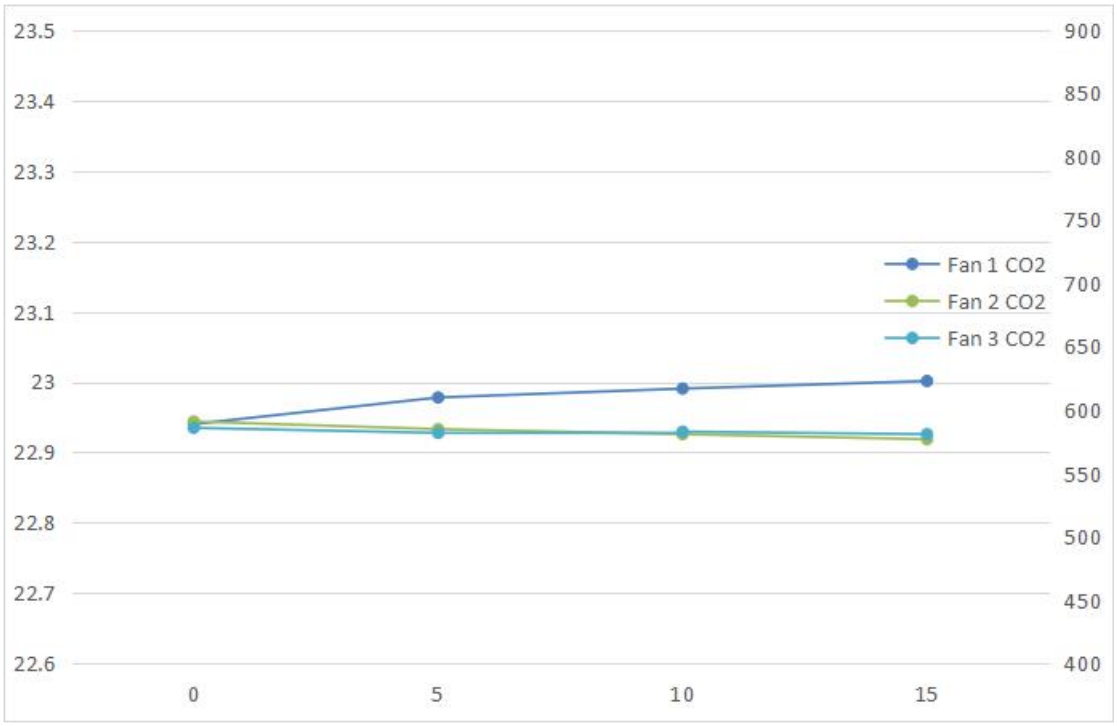

Figure 28. Changes in carbon dioxide concentration when 1 people are in the box. (school week)

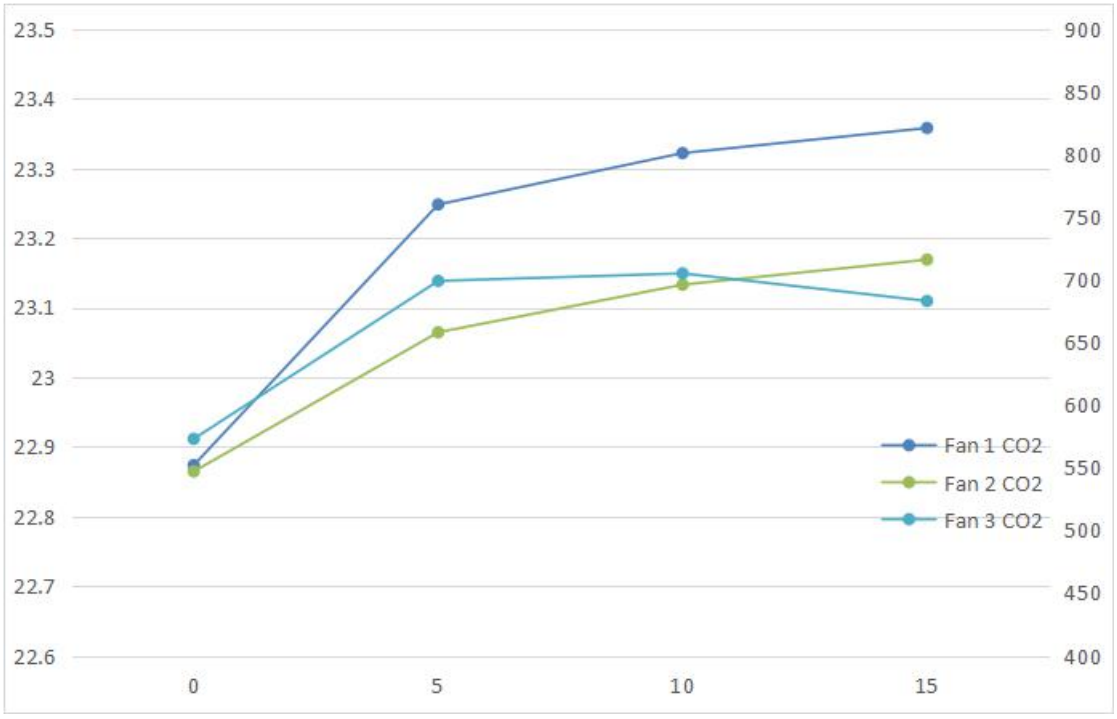

Figure 29. Changes in carbon dioxide concentration when 2 people are in the box.(school week)

It can be seen from the table above that the baseline value of the normal school week carbon dioxide concentration is a little higher than that at home -study week. This should be due to the increase of the number of people in the school hall, which led to the increase of carbon dioxide concentration. But the trend of the overall change in the two weeks is roughly the same. When there is no person in

the box, the carbon dioxide concentration basically does not change. When there are two people in the box, the carbon dioxide concentration changes relatively. It can be concluded that people in the box mainly have a greater impact on the concentration of carbon dioxide in the box. And increase as the number of people in the box increases, the range of change also becomes larger.

9.CONCLUSIONS

According to the results of the experiment, the temperature changes indoor and outdoor air are not very large during the entire experiments. Due to the light transmission of the box, under direct sunlight, if two or three people stay in it and the air conditioner is not turned on, they will feel a little stuffy. Even if a person does not turn on the air conditioner when the temperature is high, they may feel uncomfortable. The first to second gear air speed is suitable for one person to work in the box, and the second to third gear is suitable for two people. According to the adjustment of different fan speeds, people working in the box can be placed in the most comfortable environment.

I think this kind of box is suitable for crowded and noisy offices, cafes, schools and other public places with a lot of noise. Because this box can provide you with a quiet and comfortable office environment at any time, you can work and study alone, or it can be used for private conversations between two or three people. At the same time, the box can continue to be improved. Since both sides of the box are completely transparent, I think it is possible to add retractable curtains, which can not only block part of the sunlight, but also provide a more private environment. And green plants can be placed inside the box, which can effectively absorb carbon dioxide and release oxygen. According to experiments, we can also see that the indoor carbon dioxide content increases with time. Green plants can help to provide a continuous aerobic environment.

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